Absence of Ship Rat *Rattus rattus*, and Norway Rat *Rattus norvegicus*, on Ouvea (Loyalty Islands, New Caledonia): consequences for conservation

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A rat trapping campaign was conducted from July to December 1994 on Ouvea in the Loyalty Islands, New Caledonia. Locations of rat traps took into account different geographic sectors (North, Centre, South and Islets) and different habitats (forest, crop fields, coconut plantations, houses). The campaign encompassed a total of 1 363 trap nights and autopsy data were collected on rodents that were captured. Vertebrate remains from Barn Owl roosts were also collected and examined to determine which rat species were present. For the whole campaign the corrected trap success rate was 9.5 rodents per 100 trap nights. No significant variations in the trap success rate were observed in relation to geographic sector or habitat. Ninety-eight rodents were captured and 64 identified: six *Mus musculus* and 58 *Rattus exulans*. No *Rattus rattus* and no *R. norvegicus* were caught. Similarly, the only species identified from material found in Barn Owl roosts were *M. musculus* and *R. exulans*. Observation of the fauna and environment on Ouvea provided some indirect evidence to confirm the absence of both *R. rattus* and *R. norvegicus*. The history and geographical characteristics of Ouvea, and certainly chance, could explain the fact that these two species never reached the island. With regard to rat species, Ouvea's situation is remarkable and unique in the Pacific for inhabited islands of comparable size and level of development. Considering the dramatic and well known effects resulting from the introduction of rat species such as *R. rattus* and *R. norvegicus* on small Pacific Island environments, the authors have alerted local authorities and the population of Ouvea, and have proposed initial measures as part of an action plan.

Key words : Rat spp, Rat Trapping, Conservation, Ouvea (Loyalty Islands), Pacific.

INTRODUCTION

TROPICAL rainforests and island ecosystems are recognized as priorities for conservation, not only because of their biological richness, but also their rate of destruction. Both the tropical rainforest and island ecosystems are found in New Caledonia, and the associated Loyalty Islands. Situated in the south-west Pacific, these islands have a high level of endemism: 80% of the 3 500 plant species are endemic (Myers 1986). With a total surface area of 19 000 km^2, the archipelago is home for 142 species of native birds (including one family, three genera and 20 species all endemic — Hannecart and Letocart 1983), 41 species of reptiles (28 endemic), seven species of bats (three endemic), and at least 300 species of endemic land snails (CTRDP 1987).

This high level of biodiversity is directly and indirectly threatened by human activity which has already lead to a significant extinction rate, as is the case on many other islands where the risk of extinction for isolated populations is inversely proportional to the available surface area (Diamond 1985). Since the arrival of human beings in New Caledonia some 3 000 years BP, at least 20 species of vertebrates have disappeared, including eight avian species. For some species (i.e., *Sylviornis neocaledoniae, Porphyrio kukwiedei*) extinction is a result of direct hunting, and of predation by Kiore *Rattus exulans* that were introduced by early settlers (Balouet 1987). More recently, at least three species are considered to be on the verge of extinction or already extinct: the New Caledonian Lorikeet *Charmosyna diadema,* the New Caledonian Wood Rail *Tricholimnas lafranayanus* and the New Caledonian Owlet-nightjar *Aegotheles savesi.*

Although all the reasons for the decline of these species are not known, predation by introduced mammals, and rats in particular, has always been a factor, recognized as the major cause of extinction on Pacific Islands (Atkinson 1985; Hay 1986; Moors *et al.* 1989, 1992; Seitre and Seitre 1992). Two other taxa are included in the International Union for the Conservation of Nature's (IUCN) threatened category: Kagu *Rhinochetos jubatus* a unique representative of an endemic family, also threatened by rats (Warner 1948; Letocart 1989); and the Ouvea Parakeet *Eunymphicus cornutus uvaeensis*, a subspecies endemic to Ouvea island in the Loyalty archipelago, the other subspecies of this endemic genus living on the New Caledonia mainland *E. cornutus cornutus*. The question of the presence of rats on Ouvea arose recently with the

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...NSERVATION BIOLOGY Vol. 2: 390–97. Surrey Beatty & Sons, Sydney, 1995.

inception of a study on the ecology and biology of the Ouvea Parakeet. The status of this bird is considered critical by the Species Survival Commission of IUCN (i.e., 50% chance of extinction within five years or two generations, (Mace and Lande 1991)) due to the loss of natural habitat and capture for the pet trade (Lambert *et al.* 1992).

The hypothesis that both Norway and Ship Rats are absent from Ouvea was formulated after a two-week census of the native parakeets in 1993, when no evidence of these two rodents was found (Robinet *et al.*, in press). According to most authors, both New Caledonia and the Loyalty Islands are habitats for the House Mouse *Mus musculus*, and the three main rat species: Ship Rat, Norway Rat and Kiore (Revilliod 1913; Tate 1935; MacMillan 1939; Green 1979; Atkinson 1985). Given the dramatic consequences for island avifauna following the introduction of Ship and Norway Rats (Atkinson 1977, 1985; Bourne 1981; Moors and Atkinson 1984), it appeared crucial to confirm the presence or absence of these two rodents on Ouvea. Hence the large scale trapping campaign was organized.

Study area

Ouvea (132 km^2, centred on 166°30′E, 20°30′S), Lifou (1 150 km^2) and Mare (650 km^2) are the three main Loyalty Islands, one of the three Provinces of the Territory of New Caledonia in the south west Pacific. In contrast to the New Caledonian mainland, the Loyalty Islands are relatively recent formations, being elevated former coral atolls from the Miocene period (22–5 million years BP). The remains of the barrier reef form cliffs around the perimeter of Ouvea, particularly on the east coast. The island plateau itself is the raised bottom of the former lagoon (Mathieu-Daudé 1989). The climate is tropical, tempered by trade winds. The average temperature is 23.5°C with the minimum average in July and the maximum average in February. Average annual rainfall is 1 200–1 600 mm, with the minimum average in September and the maximum in March. There are four seasons: one hot humid season from December to March, when cyclones can occur, and a cold dry season from July to October, separated by two intermediate seasons.

The soil is Rendzine type on limestone, originally constituted by pumice from the sea. Climax vegetation is evergreen humid forest, 15–20 m high, composed of Kohu trees *Intsia bijuga*, Buni *Manilkara dissecta* and column pine trees *Araucaria columnaris* atop the cliffs. Where forest is cleared, secondary forest takes root, characterized by *Acalypha melochia, Acacia spirorbis* and introduced species (*Psidium gajava, Lantana camara, Anona* sp.). The majority of the coastal strips are corral terraces where vegetation is scarce (*Hibiscus tiliaceus, Sterculia bullata, Lotus australis*), with sandy beaches, Coconut Trees *Coco nucifera* and Filao *Casuarina equizetifolia* at different intervals. Mangrove also grows in salty marshes on Ouvea, with *Bruguiera gymnorrhiza, Rhizophora mucronata* and *Avicenia officinalis* present (Guillaumin 1948; Schmid 1981; CTRDP 1987). The native fauna includes 43 species of terrestrial nesting birds, of which two *Zosterops* are endemic to Loyalty Islands, three species of bats endemic to New Caledonia (*Miniopterus* sp.) and two flying foxes (*Pteropus* sp.) including one endemic species, and at least 12 species of reptiles, of which one is endemic to the Loyalty Islands (Revilliod 1913; MacMillan 1939; Balouet 1987; CTRDP 1987).

Ouvea is home to approximately 4 000 people. The 30 inhabitants/km^2 represents a population density three to four times greater than Lifou and Mare. The economy is based on agriculture: coprah production, traditional root crops (yam, cassava and taro), animal farming and fishing. The main sources of income are external subsidies from New Caledonia and France. Each of the three islands has an airport with daily flights to and from the mainland capital of Noumea. All three islands also have a wharf, where cargo from the mainland is off-loaded at least once a week.

METHODS

Rat trapping campaign

The trapping campaign took place from July to December 1994. This corresponds to the relatively dry season when access to the forest is easier. Rat snap traps (EZESET) baited with cheese were used. The traps were set on the ground at 50 m intervals on random lines, without any cover, but hidden by vegetation to avoid capture of non-target species. In most cases, the traps were set for three nights and were checked every day. In some places, however, where access was difficult, traps were checked only after two or three days.

The trapping sessions were planned taking into account the four geographic sectors (North, Centre, South of the island and Islets) (Fig. 1), and the four habitats (forest, crop fields, coconut plantations and houses and gardens). The trapping programme and the nature of the field (e.g., few houses in the Centre and on Islets, plantations in the South and on Islets) did not provide significant numbers of trapping units in every category (Table 1). Nonetheless, it did enable an evaluation of the effect of "habitat" and "geographic sector" on the frequency of captures to be made, by using a Chi square test.

Trap success (or catching effort)

Trapping units where calculated using this formula: total no. of traps × no. of trapping intervals × length of trapping interval. Missing

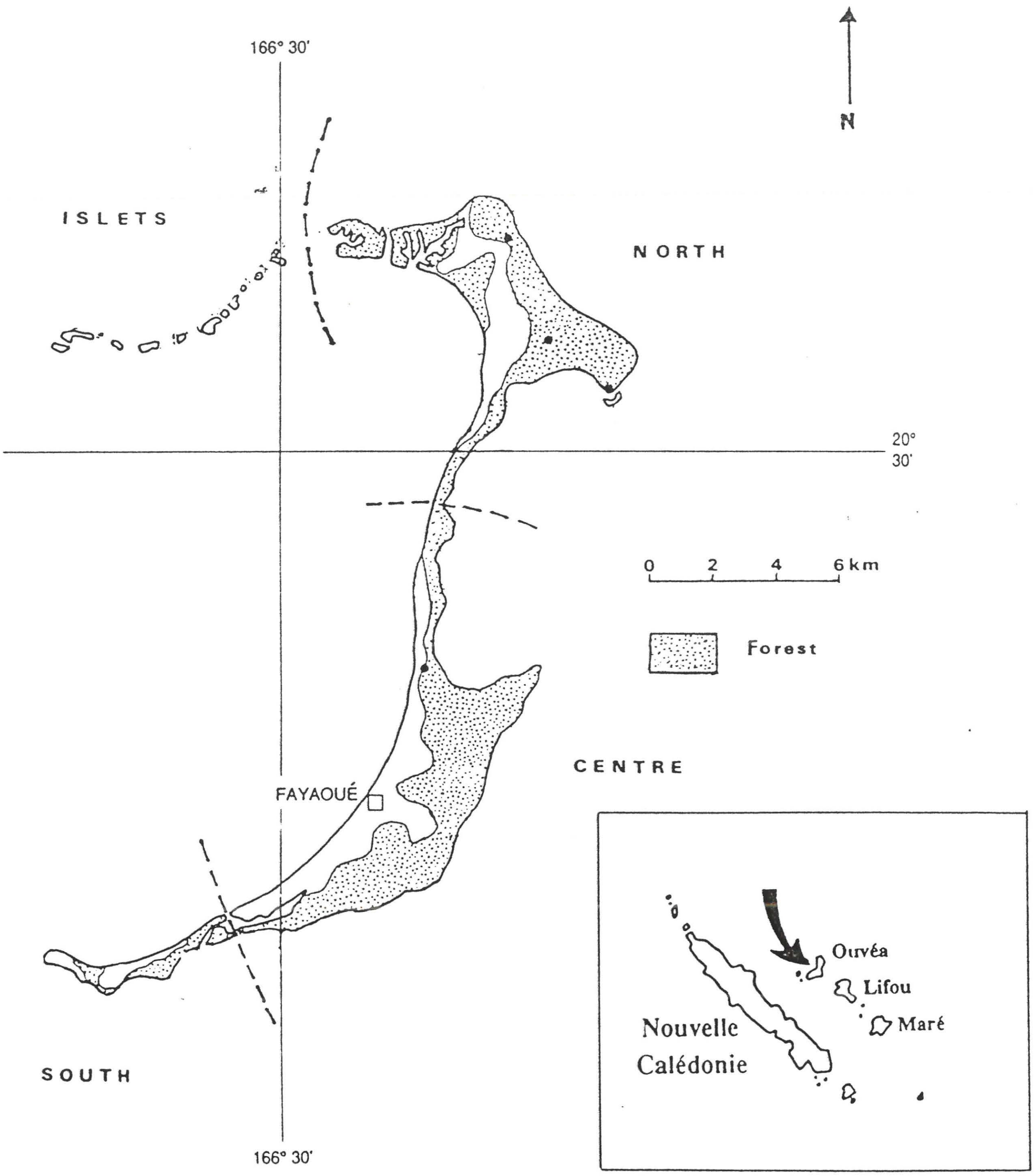

Fig. 1. Geographic sectors and location of forest on Ouvea, Loyalty Islands.

Table 1. Trapping nights by habitat type and geographical sector on Ouvea.

	North	Centre	South	Islets	Total
Forest	490	285	60	30	865
Crop fields	54	30	12	6	102
Coconut fields	72	58	120	24	274
Houses	22		100		122
Total	638	373	292	60	1 363

or lost traps were not taken into account. The Catch-effort (CE) was corrected under Nelson and Clark's method (1973) using the following formula:

$$CE = A \times 100/(TU\text{-}S/2)$$

where A is the number of rats captured; TU, the number of trapping units and S, the number of captures + sprung, empty traps.

Autopsy data

To identify species, rodents collected were examined for Head plus Body Length (HBL), Tail Length (TL), right ear length, length of the right hind foot, colour of the upper right hind foot, fur the on back and on the belly, following the procedure described by Cunningham and Moors (1993).

Analysis of material found in Barn Owl roosts (vertebrate remains)

Material, mainly bones and teeth, was collected from a Barn Owl *Tyto alba lifuensis* roost in a cave on Ouvea. These Owl pellet debris were found in soil more than 1 m deep, which indicates an old colonized roost. Rodent species present were identified on the basis of both size and characteristic shape of bones and teeth (Fitzgerald 1995).

RESULTS

Trap Success

For the whole campaign, 1 363 effective trap nights have been done, and the trap success rate was 9.5 rodents per 100 trap-nights. Comparison of trap success values for the four geographic sectors showed no significant differences (χ^2 = 4.32, d.f. = 3, P > 0.05) (Table 2). The value observed on islets must be considered with caution, given the low number of trapping units. Likewise, comparison of trap success values for the four habitat types showed no significant differences (χ^2 = 3.11, d.f = 3, P > 0.05), although trapping was slightly more successful in crop plantations (Table 3).

Autopsy data

Ninety-eight rodents were captured during the campaign. In 34 cases, only remains of the corpse were found and identification of the species was impossible. Of the 64 other rodents captured, six House Mice and 58 Kiore or Polynesian Rats were identified. No Ship or Norway Rats were caught.

There were 34 male and 30 female rodents. Size did not differ appreciably according to sex. Frequency distributions for Head plus Body Length (HBL) and Tail Length (TL) showed that most of the rodents trapped fell within a unimodal distribution, except for the small group of six animals identified as House Mice (Fig. 2 and Fig. 3). Seventy-eight per cent of the 58 rodents in the Kiore sample had HBL of between 120 and 140 mm and no individual had HBL exceeding 160 mm. Eighty-three per cent of the rats had TL of between 120 and 150 mm, with a maximum TL observed of 160 mm. The TL/HBL ratio varied from 0.84 to 1.2 with an average ratio of 1.02 (± 0.15).

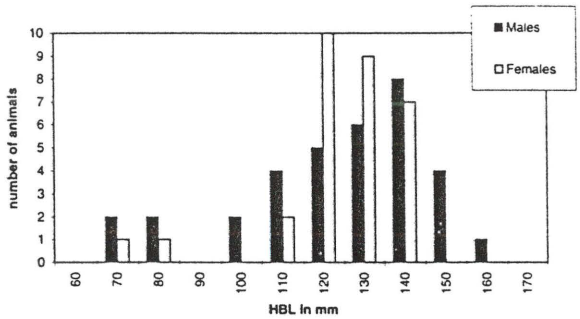

Fig. 2. Head and body length (HBL) frequency distribution for male and female rodents trapped on Ouvea (n = 64).

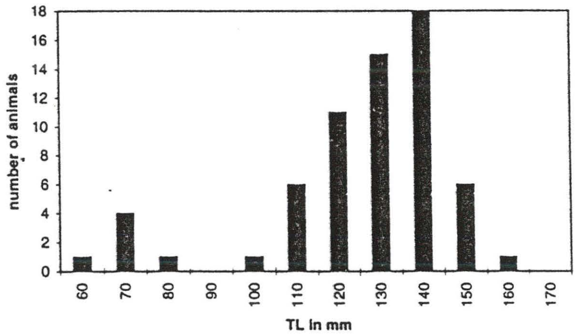

Fig. 3. Tail length (TL) frequency distribution for rodents trapped on Ouvea (n = 64).

Table 2. Corrected trap success and total rodents captured by geographical sector on Ouvea.

	North	Centre	South	Islets
Trap success	8.0	11.9	8.9	14.7
Rodents captured	39	34	20	5

Table 3. Corrected trap success and total rodents captured by habitat type on Ouvea.

	Forest	Crop fields	Coco. fields	Houses
Trap success	9.0	14.2	8.3	11.8
Rodents captured	59	11	17	11

Bones found in Owl pellets

Twelve different characteristic rodent teeth and bones could be identified in the material and determined to species. *R. exulans* and *M. musculus* were present. For *R. exulans*, at least 80 individuals were identified by the femur, which was the most common identification factor of the 12 characteristics. *M. musculus* was much less common: 13 individuals were identified (Fitzgerald 1995). One mandible from an insectivorous mammal, presumably a bat, was present in the material. Bones from birds of several species were also found. These - were isolated and identified as *Ptilinopus greii*, *Aplonis striatus*, *Zoosterops lateralis*. Bones from one or two lizards were also present (Worthy, pers. comm.).

DISCUSSION

Compared to trap success results of *R. exulans* obtained on 17 small islands around New Zealand (Moller and Craig 1987), the values obtained in this study are similar to those from islands where there were no competing species of rat (mean range from 3 to 58). On the other hand, on islands where competitors exist, trap success rates are much lower (less than 3.5). With the methods and techniques used in this study, it was impossible to obtain a precise population density estimate of Kiore on Ouvea, but this was not a primary objective. Due to the availability of food all year round, densities of Kiore and Ship rats on tropical Pacific Islands do not fluctuate as much as in temperate countries (Wirth 1972; Moller and Craig 1987). Therefore the choice of the trapping period should not be an influencing factor.

During the trapping campaign (representing a total of 1 363 trapping units) 64 rodents were captured and identified. No Ship or Norway Rats were found. Measurement of rodents captured confirmed the diagnosis of species based on morphological criteria. Tooth and bone material collected in the Barn Owl roost in a cave on Ouvea, only revealed the presence of *R. exulans* and *M. musculus*. Bones covered the entire floor of the cave to a depth of more than one metre, thus it is likely that evidence of *R. rattus* or *R. norvegicus* would have been found if these two species were present on Ouvea. The three rat and one mouse species exist in the north of the New Caledonian mainland, and similar analysis of bones found in Owl pellets in a cave in this area showed that *R. norvegicus* was most common, with *R. rattus* and *R. exulans* rare, and *M. musculus* very rare (Fitzgerald, pers. comm.). Other studies indicate that in Madagascar, where it has overrun other rodents, including endemic species, *R. rattus* constitutes a significant part of the Barn Owl's diet (Goodman *et al.* 1993; Goodman 1995). In New Zealand, Kiore have disappeared from the North Island and much of the South Island following the European contact and it has been explain by the inability of Kiore to compete successfully with other rats and mices species after their introduction (Taylor 1975).

Indirect evidence on Ouvea tends to confirm the absence of Ship and Norway Rats

No significant rat activity was observed on coconut trees on Ouvea (plantations cover approximately one-third of the island's surface area), whereas on the other Loyalty islands, the locals are obliged to secure metal bands around trunks to protect the nuts from rats. According to most authors, Ship Rat represents the major threat to coconuts, causing an average loss of 15% in the tropical Pacific, and as much as 75% losses on some islands (Meehan 1984; Moors *et al.* 1989)

Furthermore, two attempts have been made in the past to translocate the Ouvea Parakeet to the nearby island of Lifou. The first effort was made early this century with one hundred birds (Delacour 1966), with a more recent attempt in the sixties. Both failed for unknown reasons. The presence of Ship Rat on Lifou may have played a crucial role in these failures. Also of significance is the apparently healthy colony of Wedge-tailed Shearwater *Puffinus pacificus* in southern Ouvea near the main road. Given Ship and Norway Rat predation on colonial sea birds on many islands around the world (King 1973; Norman 1975; Bourne 1981; Moors and Atkinson 1984; Atkinson 1985), this may be more evidence that the species do not exist on Ouvea. Lastly, there is a high density of lizards in the forests of Ouvea compared to the forests of Lifou and Mare, indicating there is little predation on them.

In view of all these elements and the results of the rat trapping campaign, it is reasonable to conclude that both Ship and Norway Rats are absent from Ouvea at the time of writing. The most plausible hypothesis is that the species never reached the island. On the other hand, restricted trapping carried out on the two other main Loyalty Islands, Lifou and Mare, have confirmed the presence of the three rat species as well as House Mice.

Why are Ship and Norway Rats absent on Ouvea, yet found on the other Loyalty islands?

The presence of the Polynesian Rat and the House Mouse on Ouvea, and the absence of Ship and Norway Rats is a unique situation in the New Caledonian context. In the Pacific, only Rennel Island in Solomons, Rose Island in Samoa, Henderson Island in the Pitcairn group, and Little Barrier and Codfish Islands in New Zealand, have the same status with regard to rat species (even if the later two do not have mice) (Atkinson 1985; Mac Fadden, pers. comm.). Rennel Island (80 × 16 km) is bigger than Ouvea, with a permanent population of approximately 1 000 inhabitants. The island has an airport, but no harbour or wharf of any importance (Moors *et al.* 1992). The others islands cited are much smaller than Ouvea, are uninhabited, and do not have a wharf (King 1973; Bourne and David 1983; Forshaw and Cooper 1989; Veitch and Bell 1990). With its wharf, regular cargo service, airport and population of over 3 500 residents, the situation with regard to rats on Ouvea is unique in the Pacific.

Particularities of the Loyalty Islands' history and geography partially explain this situation. The first humans arrived in New Caledonia from South East Asia 1 300 years BC, and the Loyalty Islands in 900 BC at the latest. These Austronesians or Lapita people (so named after the characteristic style of their pottery) introduced Polynesian rats and probably Pacific Boa *Candoia bibroni* to the Loyalty Islands, as some authors consider the species were intentionally taken aboard for food during ocean crossings (Tate 1935; Balouet 1987). Unlike other islands colonized by Austronesians, no evidence has been found of the introduction of pigs *(Sus scrofa)*, chicken *(Gallus gallus)* and dogs *(Canis familiaris)* to New Caledonia at this time. All these domestic mammals were introduced after the discovery of New Caledonia by James Cook in 1774 (Green 1979; Balouet 1987; Mathieu-Daudé 1989).

The first European settlement in the Loyalty islands dates back to 1856–61 with the establishment of sandalwood stations on Ouvea and Mare, followed by missionaries and a few adventurers during the second half of the 19th century (Mathieu-Daudé 1989). At the end of the Sandalwood "rush" around 1860, the Loyalty islands were uncolonized, and remain so to this day. Of the 20 000 inhabitants, 98% are of Melanesian ethnic origin. Thus, this relatively late "discovery" of the Loyalty islands compared to other islands of the Pacific, along with a low level of colonization and contacts with the New Caledonian mainland during the 19th century, certainly reduced the chances of an alien species being introduced. At the beginning of this century, however, Ship and Norway rats had already colonized Lifou and Mare (Revilliod 1913; MacMillian 1939).

The wharves in the Loyalty Islands are of relatively recent construction (Mare in 1955, Lifou in 1972 and Ouvea in 1974). Before these wharves were built, ships anchored in the lagoon and goods were taken ashore aboard small boats, further minimizing the risk of introduction. Since then, the Loyalty Islands have been linked to the New Caledonian mainland by monthly vessels, and more recently at least two vessels each month. These boats make a short stop and never stay overnight. Two elements in particular may have protected Ouvea: the shallow waters of the lagoon obliged ships to anchor further off-shore than is the case for Lifou and Mare, where there are deeper lagoon waters close to the coast. Also, contrary to the situation for Lifou and Mare, no shipwrecks were reported near Ouvea during the nineteenth century (Mathieu-Daudé 1989).

Ouvea may, therefore, have been partially protected from an invasion of rats for historical and geographical reasons. Chance has certainly played a major role, more so since 1974 when the wharf was built. The assumption that *Rattus rattus* or *R. norvegicus* could have reached Ouvea in the past, only to disappear, is not supported by any other example in the region. Examples of *R. rattus* becoming extinct on islets around Corsica have been recorded (Cheylan 1988) following drought and food shortages, but only on small islets with no permanent water supply, quite unlike the situation of Ouvea.

What are the predictable effects of new species of rats being introduced on Ouvea?

There is much literature pertaining to the impact of the introduction of new species of *Rattus* on Oceanic islands. Consequences of such introductions are predictable and likely to follow well-known examples: *Rattus rattus* is considered to have caused the extinction of 30 birds species in Hawaii at the beginning of this century (Atkinson 1977), of five species (i.e., one-third of native avifauna) on Lord Howe Island after 1918 (Atkinson 1985), and again five species on Big South Cape Island in New Zealand after 1962 (Moors *et al.* 1992). A recent survey carried out on 28 islands in French Polynesia has shown that a lot of species, including the Tahitian Lory *Vini peruviana* and Ultramarine Lory *Vini ultramarina* are absent from all islands where Ship Rats are present (Seitre and Seitre 1992). A recent study on the decline of Kakerori *Pomarea dimidiata*, a flycatcher endemic to the Cook islands, has shown that Ship Rat was the main cause of decline, and that the species rapidly recovered once the rat population was controlled (Robertson *et al.* 1994).

The endemic Ouvea Parakeet, already under threat due to loss of habitat and the capture of young specimens for the pet trade, would most probably be pushed into an extinction vortex soon after the arrival of Ship Rats. A lot of other indigenous birds would surely suffer from such an occurrence, to join the list of endangered species (Robinet *et al.* 1995). Apart from this ecological aspect, introduction of Ship Rats would certainly have a major impact on coprah production and other crops as well as food stocks for animal and human consumption, thus affecting the whole economy of the island.

The impending threat has led to an action plan being submitted to local authorities. Three levels of intervention are to be considered: on the wharves in Noumea, where the freight is loaded; aboard the vessels themselves; on and around the wharf on Ouvea. Permanent bait stations using new generation anticoagulants (Brodifacoum) need to be placed and replenished regularly, as well as rat protection on mooring lines. The airport should be protected in the same manner. All interventions and devices will have to be permanent, involving total co-operation from local residents, local authorities and the shipping companies.

The Ouvea example shows that not enough is known about the distribution of rats on Oceanic islands. The overall status of the main island groups and archipelagos is now known (Atkinson 1985), but some islands within these groups — such as Ouvea — may have been spared from the invasion of some rat species, and are therefore important refuges for many endemic and other species. The impact of rodents on ecosystems, and especially on birds, is well-known. There is an urgent need to carry out a census on these islands to determine the exact distribution of the various rat species in order to prevent new introductions and the ensuing dramatic effects.

ACKNOWLEDGEMENTS

This study was carried out as part of a thesis on the biology and ecology of the Ouvea Parakeet by the main author, Olivier Robinet, for his Ph.D. from the University of Auckland. We would like to thank our supervisors, Dr Mick Clout and Dr John Craig from University of Auckland, as well as Dr Rod Hay from the Department of Conservation (Wellington, NZ).

The authors wish to thank Maurice Saumoé and Siméon Baoutouo for their substantial assistance in the field. Also to be acknowledged are Dr Nicolas Barré from CIRAD Guadeloupe (French West Indies), Dr M. Fitzgerald, Dr I. Atkinson, I. McFadden and T. Worthy for their invaluable advice on study methods and species identification.

The work received the support of the Loyalty Islands Province of New Caledonia, the Zoological Society for the Conservation of Species and Populations (ZGAP, Germany) and the Stiftung Avifauna Protecta (SAP, Germany).

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PACIFIC CONSERVATION BIOLOGY

Volume 2 Number 4

ISSN 1038-2097

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ON FRONT COVER

In the conservation of biodiversity, all organisms are important and deserving of protection. This includes these Spitfire larvae which are conspicuous and sometimes important defoliators of eucalypts. Spitfires are in the Sawfly Family, Pergidae, and have the quaint habit of exuding eucalypt oils and semi-digested foliage when threatened. In a cluster, as shown in the cover photo, this can be a potent defence, but does not deter some parrots which bite off the twig on which the larvae are clustered and eat them much like a child eating a candy apple. (Photo H. Recher).